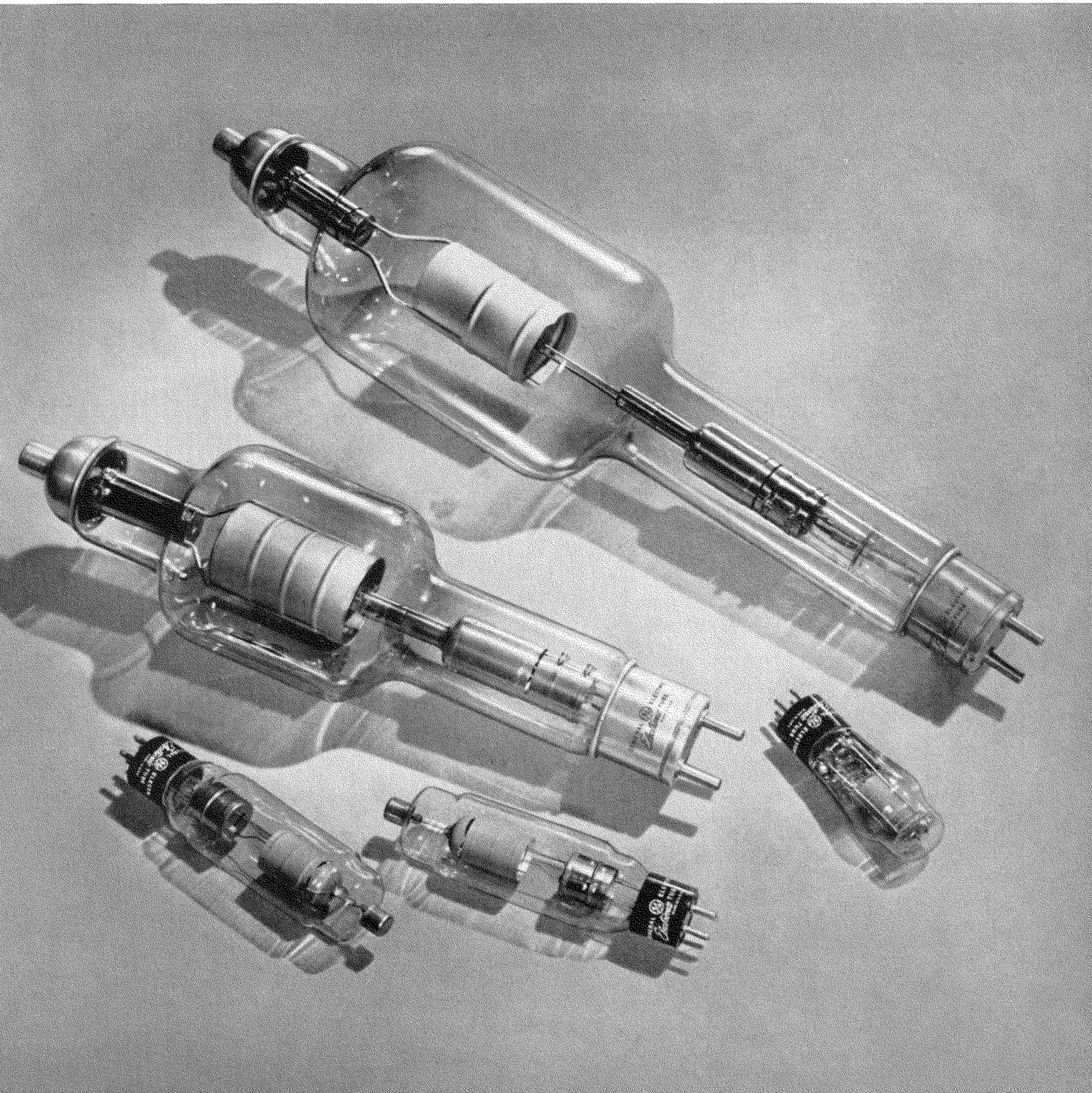
GENERAL ELECTRIC

KENOTRONS



DESCRIPTION

The kenotron is a high-vacuum thermionic tube in which no means is provided for controlling the unidirectional current flow.

The succeeding paragraphs describe the fundamentals of operation, ratings, classes of tubes, applications, maintenance and operation as well as the qualities which render these tubes particularly useful to industry.

FUNDAMENTALS OF THE KENOTRON

A kenotron consists of two electrodes, an anode and a hot cathode, located in spaced relationship within an evacuated container. Due to the elevated temperature of the cathode, negatively charged electrons are emitted from its surface and will flow to the anode (or plate) only when the anode is at a positive potential with respect to the cathode. Since the flow of electrons constitutes an electric current and takes place in one direction only in a kenotron, this tube is particularly useful for application to rectifier circuits. When an alternating voltage is applied to a kenotron and the resulting pulsating unidirectional current is used to charge a capacitor which in turn supplies the load circuit, a nearly uniform supply of direct current is obtained.

Kenotrons have no rotating parts and are therefore quiet in operation. They occupy a relatively small space and are light in weight considering the amount of power which they are rated to handle.

Kenotrons possess advantages over gas or vapor-filled tubes when very high voltages are to be rectified as the high degree of vacuum to which they are exhausted results in practically perfect insulation on the inverse cycle when the anode is negative. Since a kenotron does not depend on an internal vapor pressure for its operation, it is less sensitive to changes in ambient temperatures than gas- or vapor-filled tubes. The use of pure-tungsten or thoriated-tungsten filaments as the source of electrons permits a minimum of delay between the application of filament voltage and plate voltage.

DEFINITIONS OF HIGH-VACUUM TUBE RATINGS

General

When the terms used in the rating of high-vacuum tubes are considered, it is important to realize that the application of the limits and values given for a particular tube depends upon the operating conditions. Any nominal rating can apply only to one set of conditions and not to all the conditions encountered in practice.

The cathode or filament information is given in terms of normal heating voltage. A current figure to indicate transformer rating, is also given. The filament or cathode, except in unusual cases, should always be operated at this rated voltage rather than at rated current and the voltage should be adjusted so that the normal fluctuation in line voltage averages around this point. Normally, when this is done, a plus or minus variation of five per cent heating voltage is allowable.

KENOTRON RATINGS

In addition to filament voltage and filament current ratings, maximum ratings are given for peak inverse voltage, peak anode current and average anode current for rectifier operation.

The maximum peak inverse voltage is the highest instantaneous voltage that a kenotron will safely withstand in the direction opposite to that in which it is designed to pass current.

The maximum peak anode current is the highest instantaneous current which the filament is designed to deliver at full rated filament voltage.

The maximum average anode current is the highest average or d-c value of current which the tube is rated to carry at full rated filament voltage and beyond which the tube may be damaged due to excessive plate dissipation.

Some types of kenotrons are given additional maximum ratings for surge limiting operation which include filament voltage, peak forward anode voltage, average anode dissipation, and a peak anode current minimum. Under this type of operation the tube is used to limit a surge usually of short duration.

The maximum peak forward voltage is the highest instantaneous voltage that a kenotron will safely withstand in the direction in which the tube is designed to carry current.

The maximum average anode dissipation is the highest average wattage which may be expended in the anode under this type of operation.

The peak anode current minimum is intended as a guide to indicate the instantaneous anode current which may be expected under typical operating conditions.

CLASSES OF KENOTRONS

Kenotrons may be divided into two general classes:

1. Radiation - cooled kenotrons (sometimes cooled by immersion in oil) usually of the glass-envelope type.
2. Water-cooled kenotrons with anodes which are cooled externally by water circulation through a water jacket surrounding the anode.

APPLICATION CIRCUITS#

In general kenotrons are useful in any application involving the rectification of alternating current to provide a direct-current supply or for the suppression of intermittent high-voltage surges. The kenotron finds its greatest usefulness where the requirements call for high voltage at low current or where the range of ambient temperature variations is wide.

A typical example is the kenotron used in air filter applications. The kenotrons supply the high voltages necessary to filter the air by electrical precipitation. The air is ionized and the negatively charged dust particles adhere to plates positively charged by the kenotrons.

The kenotron is less efficient at low voltages than gas- or vapor-filled rectifier tubes, but will operate satisfactorily at peak inverse voltages far in excess of those for which gas- and vapor-filled tubes are designed.

When selecting a tube type for a particular application, consideration must be given to the ability of the tube to withstand the open circuit or inverse voltage, as well as to its ability to pass sufficient overload current in the forward direction without overheating. Electrons flow to the plate with very high velocities so that time-lag effects are negligible for rectification voltages, even at the highest power supply frequencies used in practice.

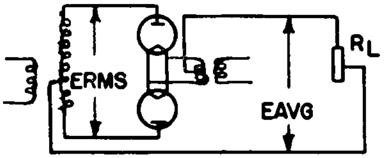
The kenotron rectifier provides a means of obtaining a higher voltage d-c supply than can be conveniently obtained by other methods. The stability of these tubes with regard to power supply frequency and their small size and quietness of operation are added advantages.

A number of rectifier circuits in which kenotron tubes may be used are shown in Figs. 1-10.

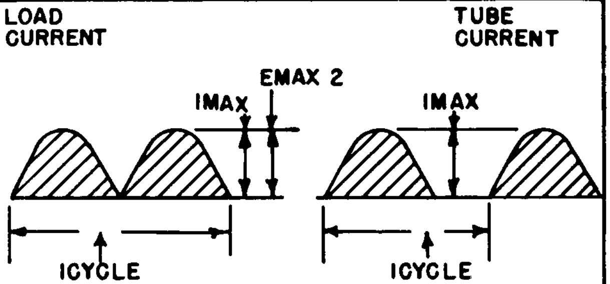
#Circuits shown in ETI-140 are examples of possible tube applications and the description and illustration of them does not convey to the purchaser of tubes any license under patent rights of General Electric Company.

NO | FIGURE | WAVE FORM

1



BIPHASE HALF-WAVE TWO ANODES



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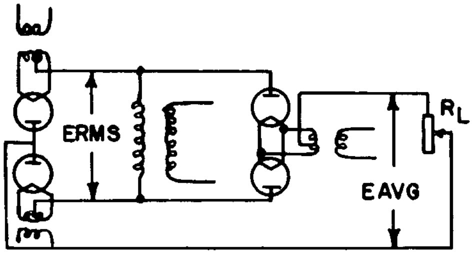
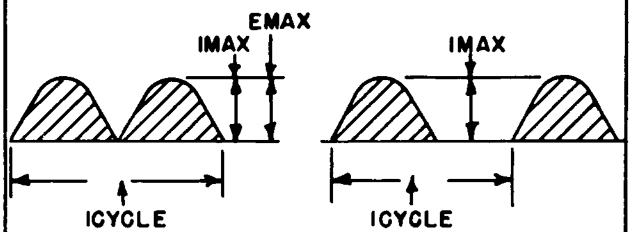


BIPHASE FULL-WAVE FOUR ANODES



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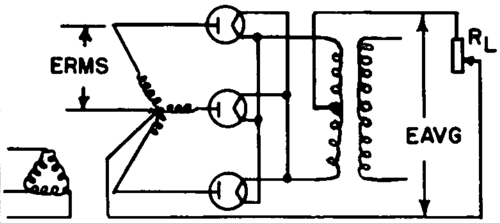
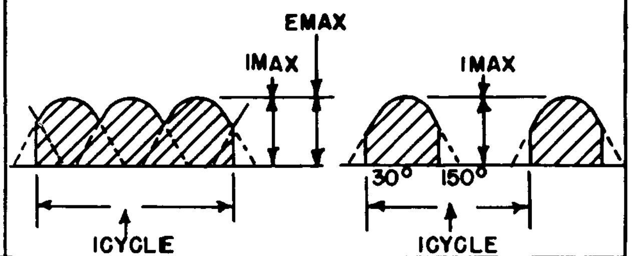


THREE-PHASE HALF-WAVE THREE ANODES



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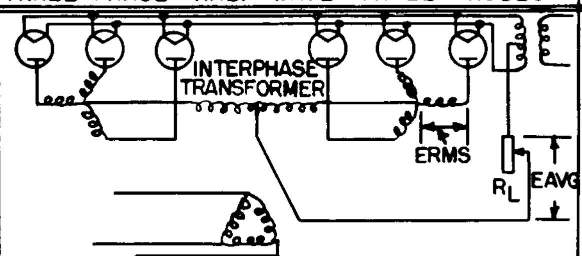
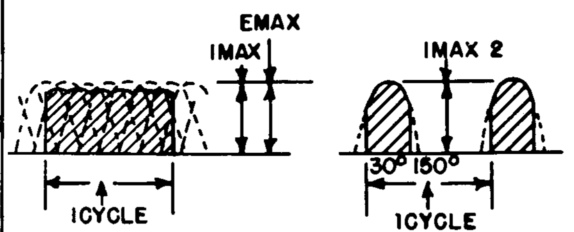


DOUBLE THREE-PHASE HALF-WAVE WITH INTERPHASE TRANSFORMER SIX ANODES



APPLICATION CIRCUITS (CONT'D)

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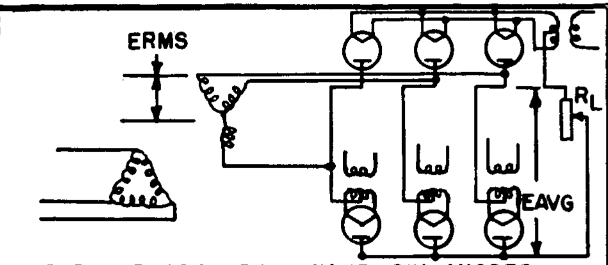
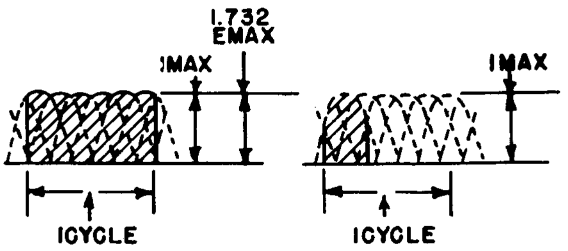


THREE-PHASE FULL-WAVE SIX ANODES



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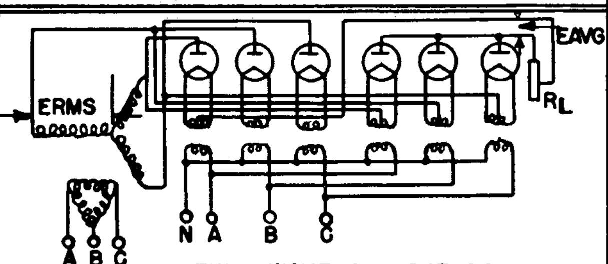
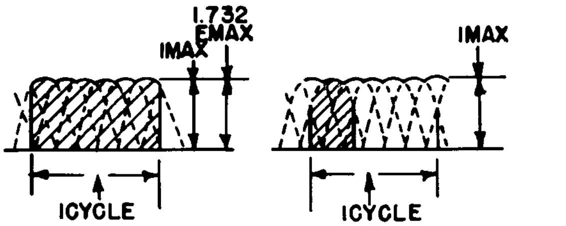


THREE-PHASE FULL-WAVE QUADRATURE EXCITATION, Δ-Y MAIN TRANSFORMER



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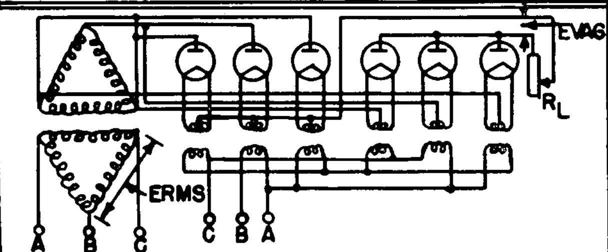
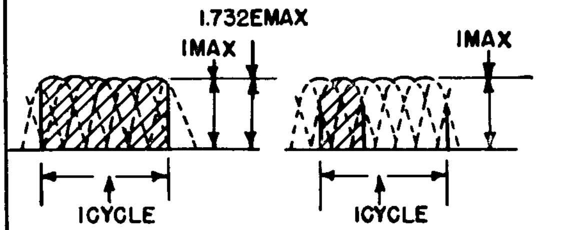


THREE-PHASE FULL-WAVE QUADRATURE EXCITATION Δ-ΔMAIN TRANSFORMER



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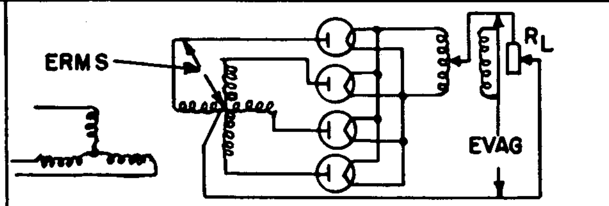
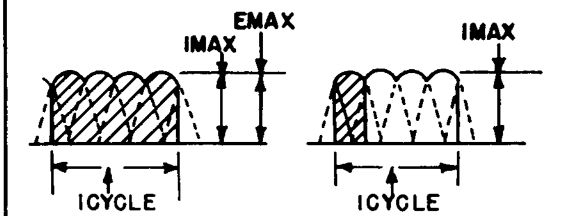


FOUR-PHASE HALF-WAVE FOUR ANODES



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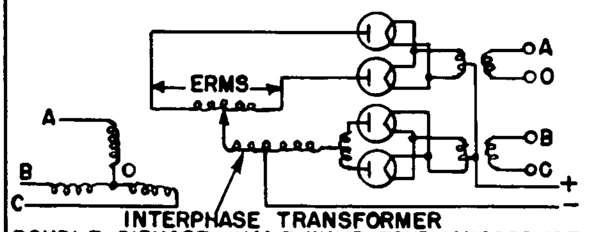
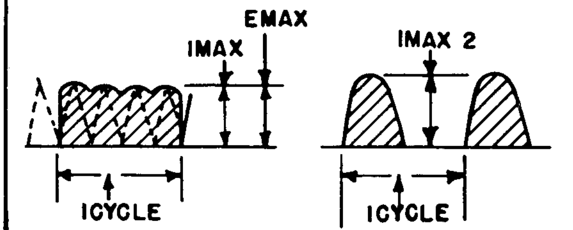


DOUBLE-BIPHASE HALF-WAVE FOUR ANODES WITH QUADRATURE EXCITATION



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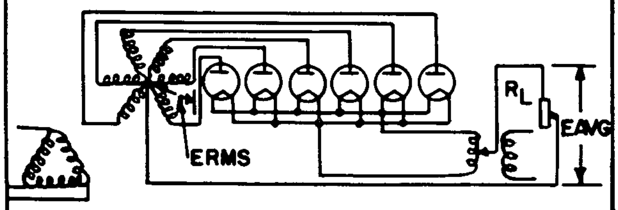
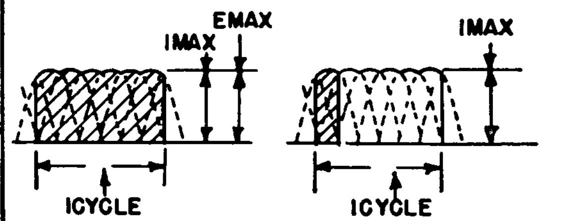


SIX-PHASE HALF-WAVE SIX ANODES



USEFUL RATIOS

FIG. NO.	TUBE I(AVG) / LOAD I(AVG)	E-AVG	E-INVERSE	I-AVG
1	0.500	0.318 E-MAX 0.450 E-RMS	E-MAX 3.140 E-AVG	0.636 I-MAX
2	0.500	0.636 E-MAX 0.900 E-RMS	E-MAX 1.570 E-AVG	0.636 I-MAX
3	0.333	0.827 E-MAX 1.170 E-RMS	$\sqrt{3}$ E-MAX 2.090 E-AVG	0.827 I-MAX
4	0.167	0.827 E-MAX 1.170 E-RMS	$\sqrt{3}$ E-MAX 2.090E-AVG	0.827 I-MAX
5	0.333	1.650 E-MAX 2.340 E-RMS	$\sqrt{3}$ E-MAX 1.050 E-AVG	0.955 I-MAX
6	0.333	1.650 E-MAX 2.340 E-RMS	$\sqrt{3}$ E-MAX 1.050 E-AVG	0.955 I-MAX
7	0.333	0.955 E-MAX 1.340 E-RMS	E-MAX 1.050 E-AVG	0.955 I-MAX
8	0.250	0.900 E-MAX 1.274 E-RMS	2.220 E-AVG	0.900 I-MAX
9	0.250	0.318 E-MAX 0.450 E-RMS	3.140 E-AVG	0.318 I-MAX
10	0.167	0.955 E-MAX 1.350 E-RMS	2.090E-AVG	0.955 I-MAX

APPLICATION CIRCUITS (CONT'D)

When a kenotron is placed in series with an alternating-voltage supply and the resulting pulsating current used to charge a condenser which in turn supplies a load, only one-half of the alternating voltage is used. Such a circuit while satisfactory in some cases is not efficient. In general, multiphase circuits utilizing both half cycles of the alternating voltage (fullwave operation) yield a higher average output voltage and current for a given tube size. The variation in the d-c output voltage known as the ripple is also considerably reduced with multiphase circuits. In some circuits tubes are operated in series to obtain higher average d-c output voltages than could be obtained with a single tube without exceeding the maximum rated peak inverse voltage of the kenotron. In other applications tubes are operated in parallel to provide greater d-c output current without exceeding the current rating of the kenetrons.

The circuits shown in Figs. 1-10 as well as variations of them will be found useful in such applications as air filters, cable testing, smoke precipitaters, radio transmitters, x-ray and other electrophysical and electro-chemical uses requiring high direct voltage at moderate currents.

Fig. 11 shows a circuit for testing high-voltage cable where extremely high voltage direct current is required.

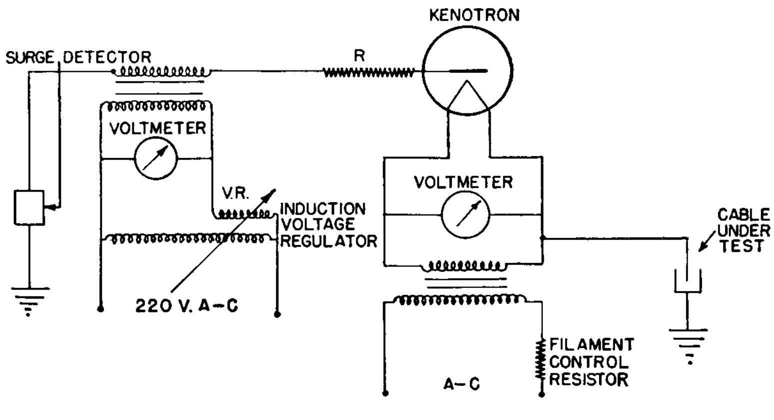


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Fig. 11—Circuit for High-Voltage Cable Tester

INSTALLATION

Cooling

Free circulation of cool air around the glass bulb should be maintained. High temperature air from other apparatus should be prevented from circulating around the tubes. If desired the tubes may be immersed in a tank of oil with the transformers.

Electrical

Filament power should be supplied from a filament lighting transformer insulated for the proper voltage, and provided with a secondary midtap for the plate circuit return lead. The filament excitation supply must be provided with suitable resistors or other regulating devices to apply the power to the filament gradually and to adjust it accurately during operation. The filament voltage should be measured directly at the filament terminals.

The installation of all wires and connections should be made so that they do not lie on or close to the glass of the kenotron. An air space of approximately the length of the tube should be maintained between the bulb and any metallic body during operation. Otherwise, corona discharge may develop and result in puncture of the glass bulb.

OPERATION

Kenotrons should be operated within the maximum ratings given in the Technical Information* in order to obtain maximum tube life and performance.

The ratings given in the Technical Information* prescribe two limiting operating conditions. The first, the maximum peak inverse voltage, is a value determined by the insulation between electrodes of the tube. This is the highest voltage that the tube will insulate on the half cycle when no currents are passing through the tube. Line surges, circuit capacitance, wave form distortion and the maximum peak voltage of the applied alternating voltage may cause the inverse voltage to exceed the maximum peak voltage rating.

The second limiting value is the power dissipation of the anode which is determined by the d-c load current almost regardless of the voltage across the load. As the design of the circuit especially the amount of capacitance in the circuit, is a major factor in determining the amount of current available in a given rectifier, oscilloscope measurements of this current should be made if any doubt exists as to the magnitude. If the kenotron is to be operated at full peak current ratings, it will be necessary to maintain exactly the rated filament voltage. If the peak current to be drawn is less than the full rated value, the allowable filament voltage regulation increases as the value of the peak current decreases.

The following tabulation shows the reduction of the maximum peak current with reduced filament voltage:

Filament Voltage % of Rated	Maximum Peak Current % of Rated
100	100
95	65
90	40
85	25
80	10

Excessive anode temperature is an indication of abnormal voltage drop in the tube and is usually caused by low filament temperature. Filament voltage greater than the rated value, while increasing the maximum peak current available, will result in decreased tube life.

Careful handling and conservative operation will be amply repaid by longer and more uniform tube life.

**Note:* *The ratings and characteristics of a particular tube are given under Technical Information on the Description and Rating Sheet for that tube.*

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